REMOTE SENSING APPLICATIONS IN FORESTRY

VIGOR LOSS IN CONIFERS DUE TO DWARF MISTLETOE

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ABSTRACT

This project, intended to develop practical remote sensing techniques for detecting and evaluating vigor loss in forest conifers due to dwarf mistletoe, was initiated in June, 1970. Eastern dwarf mistletoe (*Arceuthobium pusillum*) infection of black spruce (*Picea mariana*) is presently being investigated. A tower-tramway system, 100 feet high, was erected over an infected stand in northeast Minnesota in June and multiband/multidate photography was initiated in July and is continuing. Four 70mm film-filter combinations were used in a multicamera unit: Plus-X/Wratten 58, Plus-X/Wratten 25A, Aero Infrared/Wratten 89B, and Ektachrome Infrared/Wratten 12. The stand of mistletoe-infected black spruce under the tramway is being photographed three times per day (0900, 1200 and 1500 local sun time) at approximately 10-day intervals. An extensive test site, several square miles in area, was selected in north-central Minnesota for the purpose of testing photographic specifications developed on the tramway test site. One aerial photographic flight at a variety of altitudes was accomplished over the extensive test site in August. Data analyses are not available at this time because data collection for the current season is not as yet completed.

ACKNOWLEDGMENTS

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INTRODUCTION

Dwarf mistletoes cause major losses in many important coniferous tree species and, as a consequence, economically effective control measures are urgently needed. Detection of infected trees and infection centers is essential to a successful control program, but currently available detection techniques are of limited value.

Eastern dwarf mistletoe (Arceuthobium pusillum) in black spruce (Picea mariana) is considered to be ideally suited to research involving tree disease detection. Contrary to the western dwarf mistletoes, disease development is more uniform and occurs in stands that are essentially pure black spruce. Only one species of Arceuthobium is involved and tremendous acreages of diseased trees (the trees on approximately 7% of the 2¼ million acres of spruce type in Minnesota are estimated to have the disease), in all stages of development, are available for study. The stands are usually of uniform age without overstories and the terrain is level, making it easy to locate plots and photograph them from the air. Black spruce is not a large tree and, since so many examples of different stages of infection are available, there is no problem in finding and cutting samples for examination. Therefore, black spruce is thought to be an ideal species with which to initiate a study of dwarf mistletoe detection since, in addition to its commercial value, it is probably the most amenable to detection.

Dwarf mistletoe in black spruce can very likely be controlled by eradication of infected trees; i.e., through the use of burning (French, Meyer and Anderson, 1968.) Ongoing experiments with prescribed burning in Minnesota have thus far produced very encouraging results in terms of total eradication, but the first step in an overall control effort is, necessarily, the detection of the infection centers and this must be reasonable in cost. Remote sensing has, of course, been suggested as a possible solution to the detection problem and has, in fact, been tested successfully by Meyer and French (1967), but only on advanced stages of infection (Figure 1).

Possibilities for significant levels of detection at orbital scales are encouraging, since infection centers as small as five acres were found to be visible on conventional panchromatic and infrared aerial photography which had been reduced and degraded to scales smaller than 1:250,000 as illustrated in Figure 2. The multidate (sequential) aspects of orbital remote sensing are also of interest in the study and analysis of dwarf mistletoe infection centers, due to the possibilities for calculating rates-of-spread and more reliable estimates of timber loss. A study of this nature by Meyer and French (1966) using conventional aerial photography and local aerial volume tables showed that sequential imagery can be used for calculating the spread of dwarf mistletoe and the losses involved (Figure 3).

This project has two basic long-range objectives: (a) determination of the applicability of multiband/multidate photo imagery to the detection and quantification of coniferous forest volume losses due to dwarf mistletoe infections, and (b) the development of optimum imagery specifications and practical survey techniques utilizing ERTS capabilities per se, or multistage (satellite-aerial-ground) capabilities. As a start in this direction, the work during this first year of operation concerned itself with the

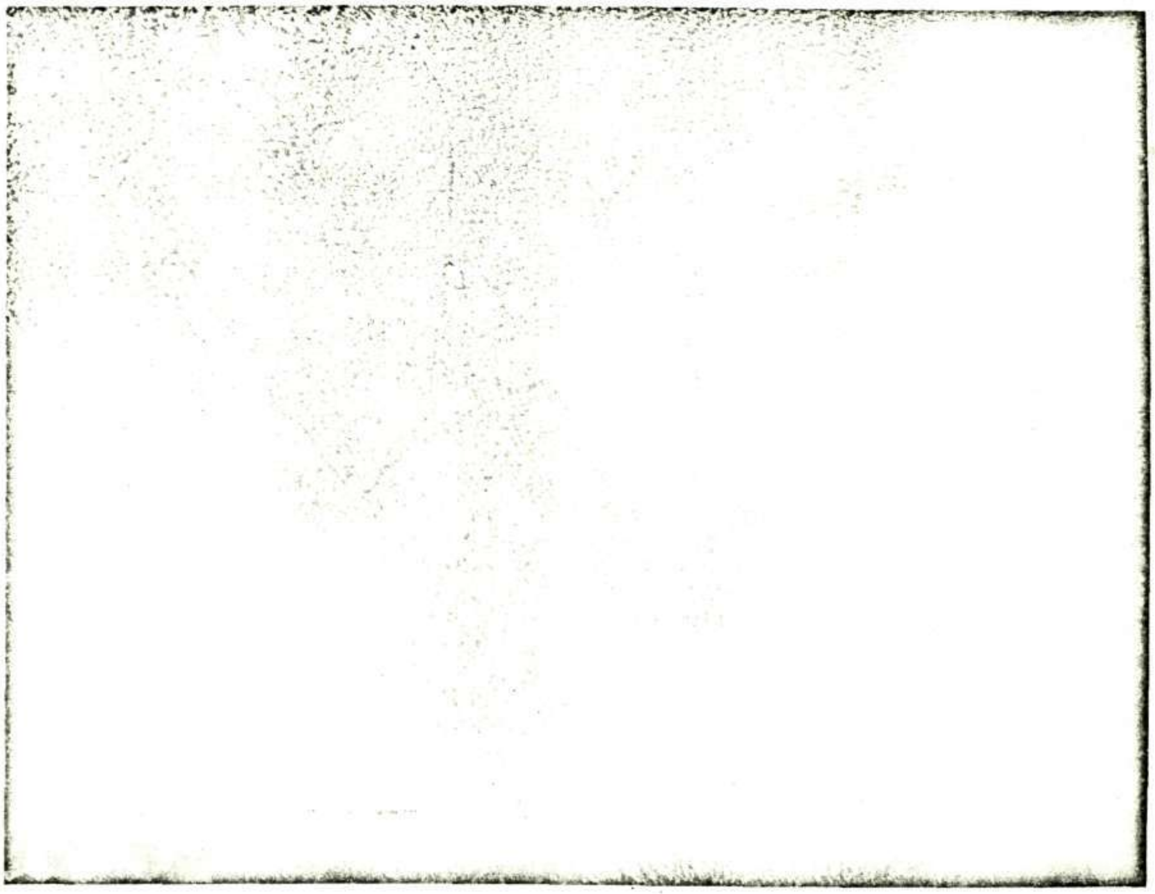

Figure 1. Portion of an Ektachrome Infrared/Wratten 12 aerial photograph of dwarf mistletoe-infected black spruce in Koochiching County, Minnesota. The photography was flown with a Zeiss RMK A 15/23 camera on August 28, 1965. RF = 1:24,000. Mistletoe infestations are the "moth eaten" areas appearing in the upper right quadrant.

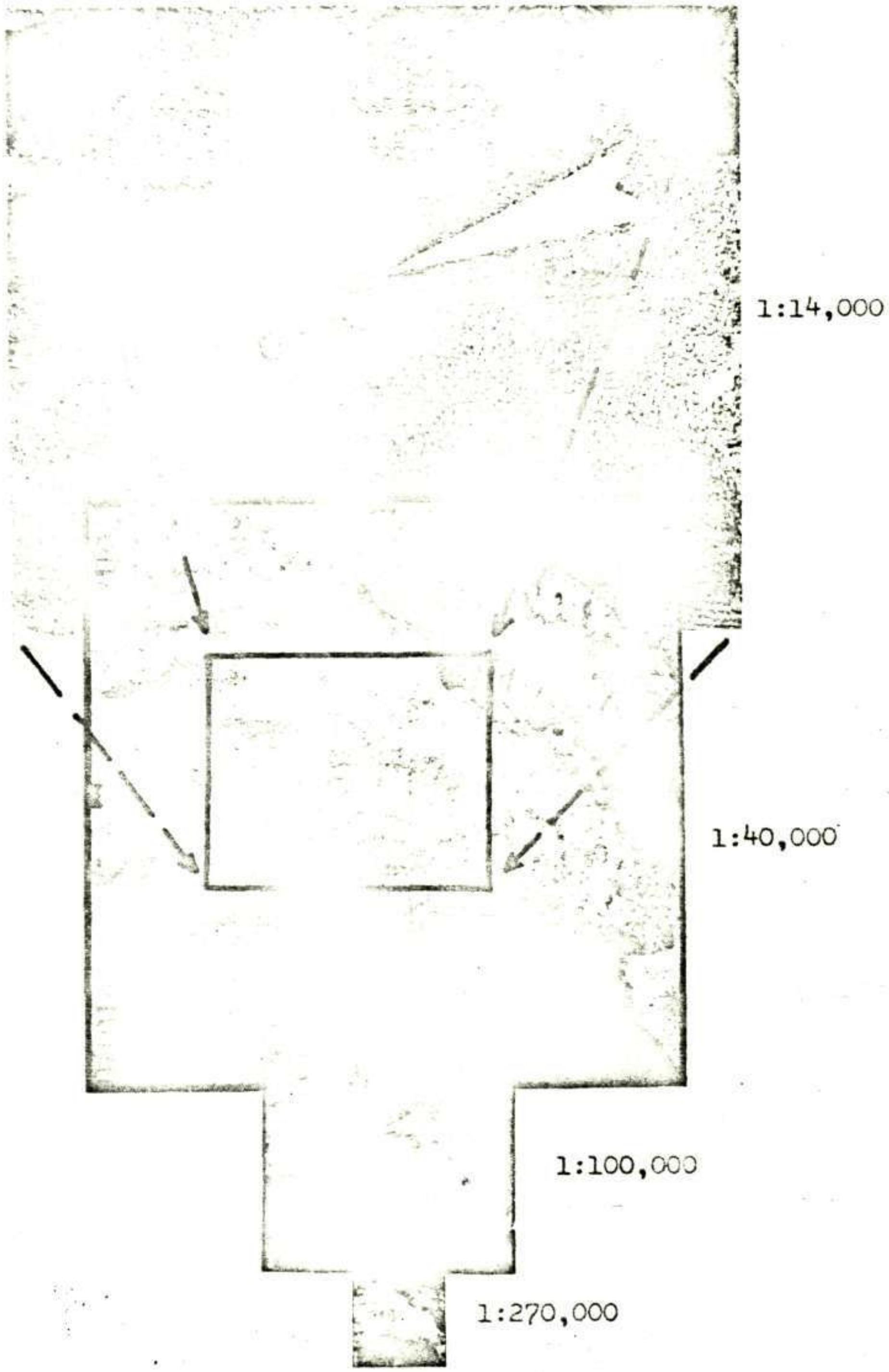

Figure 2. In spite of degradation and reductions in scale from 1:14,000 to less than 1:250,000 dwarf mistletoe infection centers as small as four to five acres are still visible.

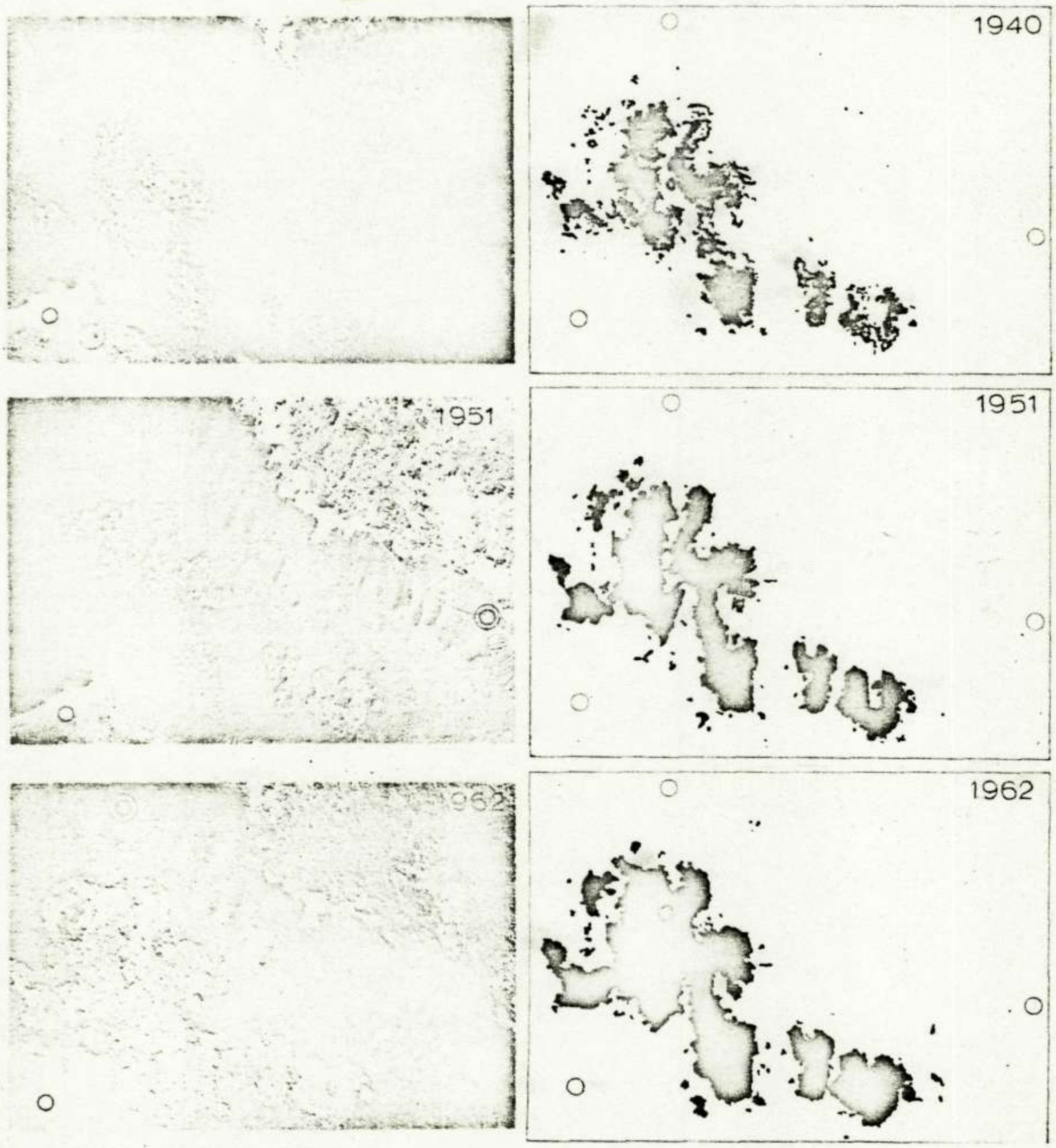

Figure 3. Aerial photos and trace maps (1940, 1951, and 1962) of the same black spruce stand in northern Minnesota illustrating the increase in area of trees killed by dwarf mistletoe over a 22-year period.

following:

1. The procurement of low-altitude, multiband/multidate photography of a relatively small, intensively ground-truthed test site employing a tower-tramway multicamera system. The ultimate objectives of the data collected on this intensive site are to determine the effects of sun angle, light intensity, season, atmospheric conditions, conditions of infected trees and development stage of the parasite upon the comparative reflective characteristics of healthy and diseased trees.
2. Selection of an extensive test site for the purpose of evaluating promising film-filter combinations at low, intermediate and high flight altitudes with photo aircraft.

LOCATION OF STUDY AREAS

Test Site I (Intensive) involves a 100 x 100 foot plot which is monitored by the tower-tramway multicamera system. It is located on the Fond du Lac State Forest in Carlton County, Minnesota. Test Site II (Extensive) is in the George Washington State Forest in Koochiching County, Minnesota, and includes several square miles of black spruce forest with a considerable number of infection centers scattered through it. Locations of the two test sites are indicated in Figure 4.

PROCEDURES

Tramway System Development and Operation

A 70mm quadricamera unit (Figure 5) had previously been developed at the University of Minnesota School of Forestry and reported upon by Ulliman, Latham and Meyer (1970). In the manner described by Wear and Weber (1969), two towers were erected 100 feet apart in a black spruce swamp at Test Site I

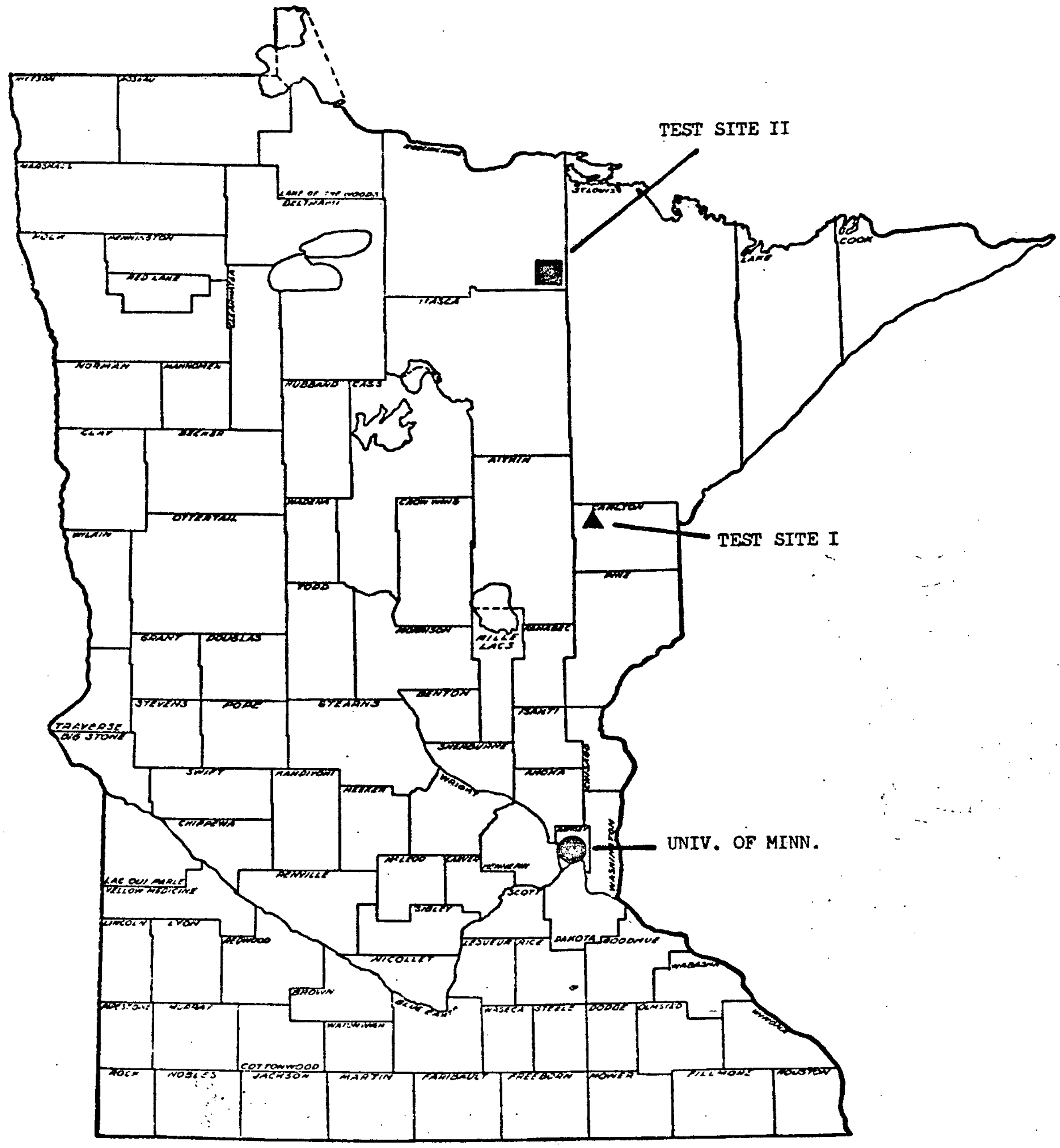

Figure 4. Map showing the location of dwarf mistletoe infection center test sites in Minnesota.

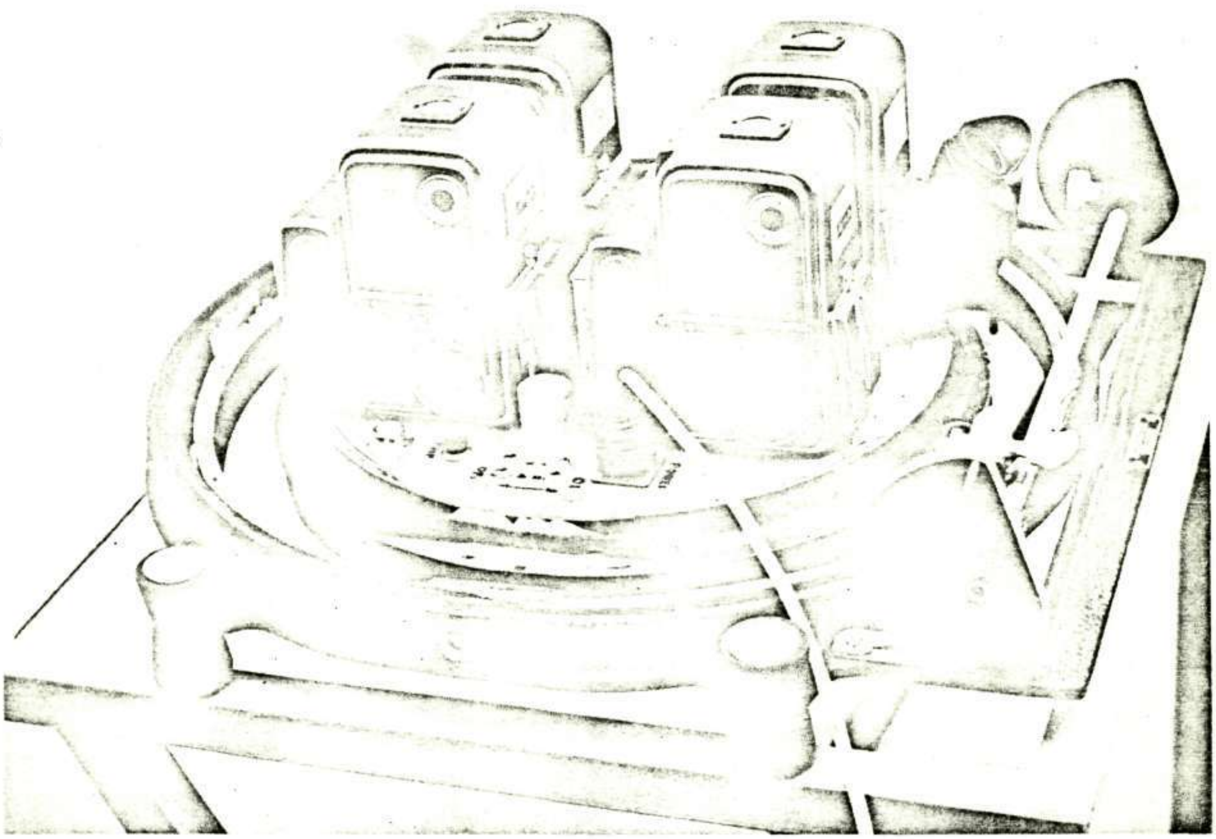

Figure 5. University of Minnesota School of Forestry 70mm quadricamera unit.

in northeastern Minnesota as illustrated in Figures 6 and 7. Since 50mm focal length lenses were to be used with the Hasselblad quadricamera unit, this provided a 100-foot strip of coverage between the two towers. The ground plot contained both healthy spruce and spruce with dwarf mistletoe and, overall, presented a considerable variety of stages of infection, size, form, age and condition class.

Initially, major difficulty was experienced in firmly anchoring the towers due to our inability to reach mineral soil under the peat at several anchor locations. Once firmly anchored, a double-cable tramway system for the camera platform (Figure 8), a haulback system and means for electrically tripping the cameras from the ground were installed.

The initial photography was accomplished on July 19, 1970, using the following film-filter combinations:

<u>Camera No. 1</u> -- Panchromatic Plus-X/Wratten 58 filter

<u>Camera No. 2</u> -- Panchromatic Plus-X/Wratten 25A filter

<u>Camera No. 3</u> -- Aero Infrared /Wratten 89B filter

<u>Camera No. 4</u> -- Ektachrome Infrared/Wratten 12 filter

These same film-filter combinations were used for all subsequent tramway and aerial photography. A sample of the tramway multiband photography is shown in Figure 9.

Following the trial runs, the operational procedures used for the remainder of the photographic season were as follows:

<u>Times of photography</u> - 0900, 1200, 1500 local (sun) time.

<u>Dates of photography</u> - Approximately every 10th day (July 22, August 1, August 10, August 20, September 1, September 12 and September 26.

<u>Performance of photography</u> - For each tramway flight, exposures

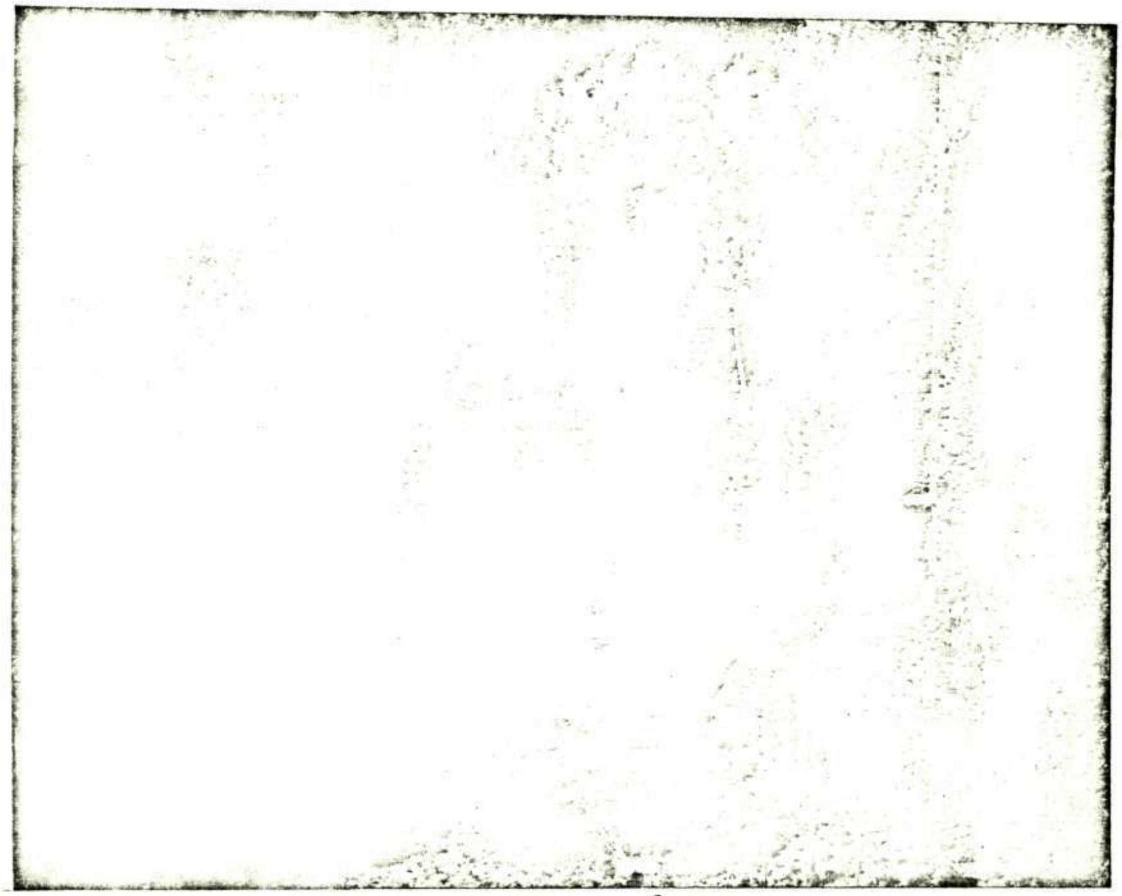

Figure 6. Oblique aerial view of the tower-tramway system on Test Site I. Note gray scale target on left tower.

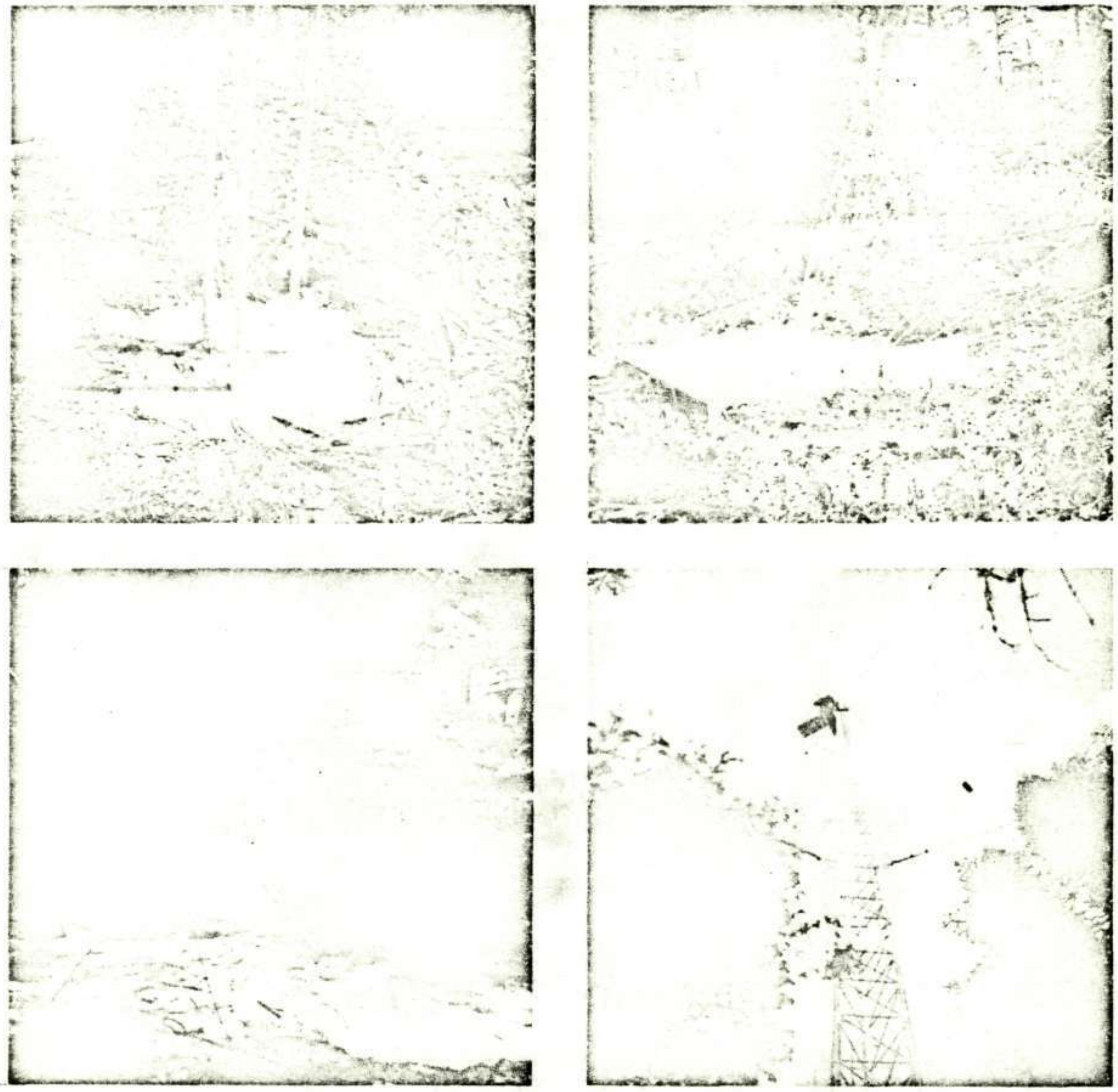

Figure 7. Tower-tramway installation and construction details.

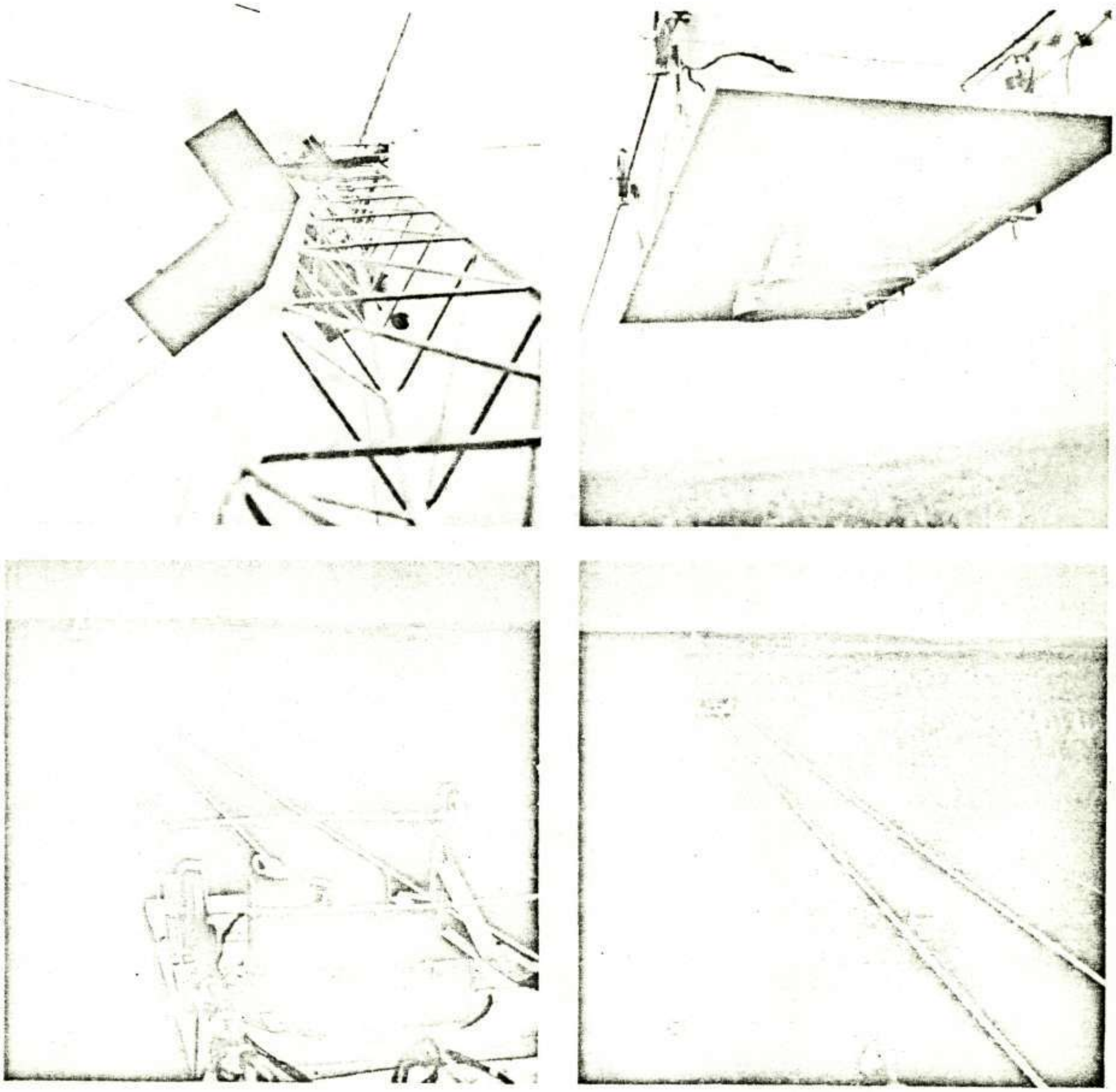

Figure 8. Views of camera platform and tramway in operation.

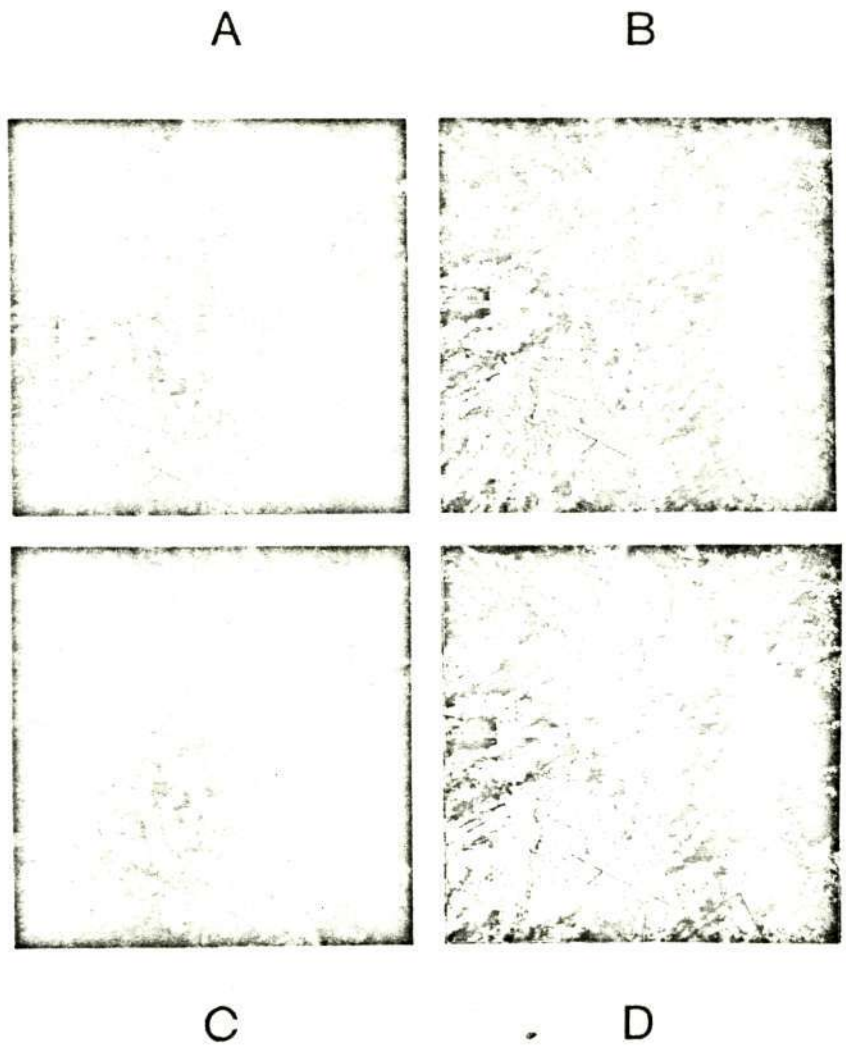

Figure 9. Example of a multiband exposure from the tramway where: A = Plus-X/Wratten 58; B = Plus-X/Wratten 25A; C = Aero IR/Wratten 89B and D = Ektachrome IR/Wratten 12. Camera focal length = 50mm; time of photography - 1200 local sun time. Note gray scale targets.

were made at 10-foot intervals along the tramway. Exposures were repeated during each time period in such a manner as to bracket the estimated f/stop and shutter speed. Exposure meter readings (Weston and G.E. meters) were also taken periodically for later checks against pictorial results.

Weather observations - Immediately prior to each photographic series, the following weather observations were taken:

a) Wet and dry bulb temperatures - with a sling psychrometer at the top of the tower.

b) Wind speed and direction.

c) Horizontal visibility estimated from known objects.

d) Estimate sky condition and types of clouds.

e) Net radiation by means of a recording pyrometer located 10 miles east of the tramway site.

f) Synoptic surface maps and upper air soundings are being collected for periods of photography.

Film care and processing - To reduce image quality deterioration, films were removed from freezer storage at the latest possible time before use. Films were, thereafter, kept as cool as possible and the interval between exposure and processing kept at a minimum.

To provide tonal reference standards for later image analysis (e.g., microdensitometer), gray scale targets (one dark, one light) of known spectral characteristics were located on a shelf on one tower, at approximately average tree top height (see Figure 10). In addition, a black and white resolution target was placed on the ground near one end of the plot.

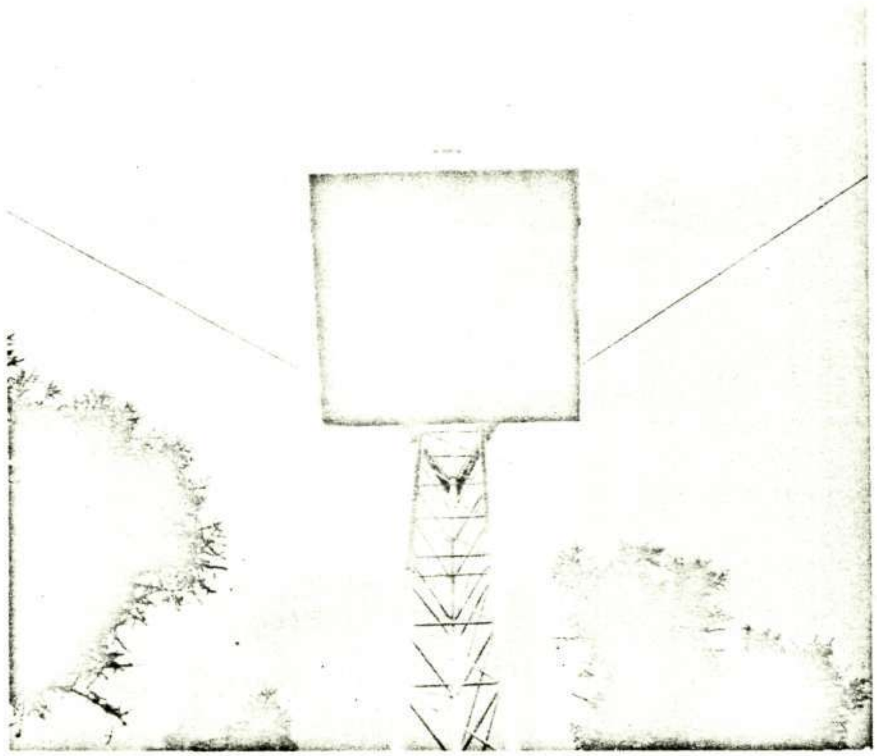

Figure 10. Bottom view of gray scale target shelf on tower.

Aerial Photography

To ultimately test the findings from the tramway photography at higher altitudes, a light aircraft was modified to accept the quadricamera unit (Figure 11). An initial flight with this aircraft was made on August 17 over Test Site II (Extensive) -- an example of which is shown in Figure 12. The same film-filter combinations used on the tramway were employed at a variety of altitudes producing photo scales of 1:8,000, 1:16,000, 1:32,000, 1:64,000 and 1:90,000.

Camera problems prevented complete stereoscopic coverage at all scales, and delay in reaching the target area resulted in sunspotting.

Ground Data Collection

On September 1, 1970, 48 live black spruce in the 100 x 100 foot Study Area I (Intensive) plot were marked on a working set of tramway photography and each tree was similarly numbered on the ground with metal tags and paint. Each tree was carefully ground-measured, examined and classified as to the absence, or presence, of infection -- 28 of the trees were healthy, 20 were infected. Infected trees were classified as to the amount of infection and seed production.

Data Interpretation

Since data collection is still under way, data analyses have not been initiated. Some preliminary imagery comparison work has been accomplished with a B & L Zoom 70 stereoscope on a Richards light table modified to display the four films simultaneously. Also, an attempt was made at fabricating an image enhancement system by means of $2\frac{1}{4} \times 3\frac{1}{4}$ inch projectors, but was abandoned because of the need for a more sophisticated optical system than local capabilities and funding levels will currently allow.

It was pointed out earlier in this report that estimated film

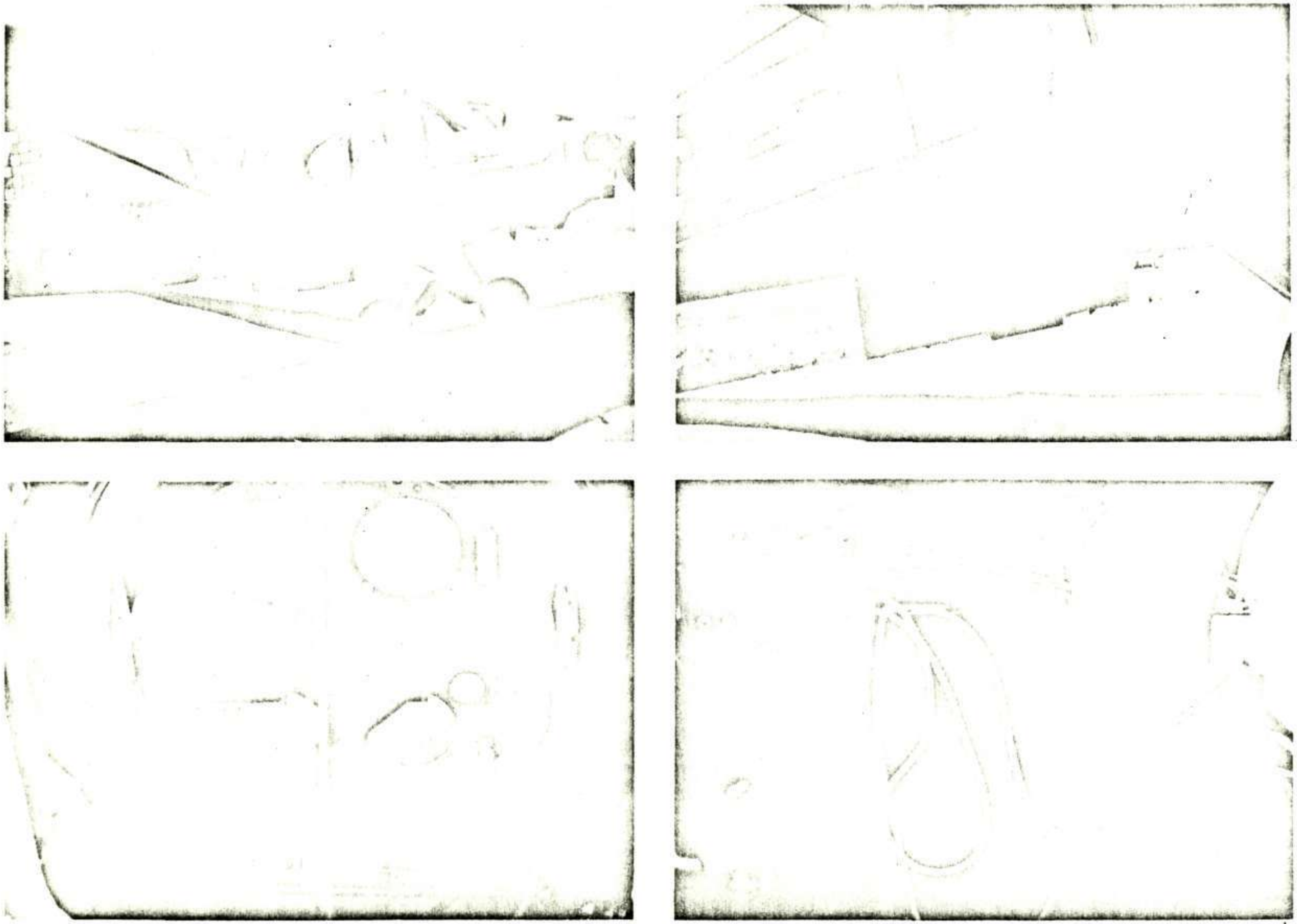

Figure 11. Exterior and interior views of modified aircraft.

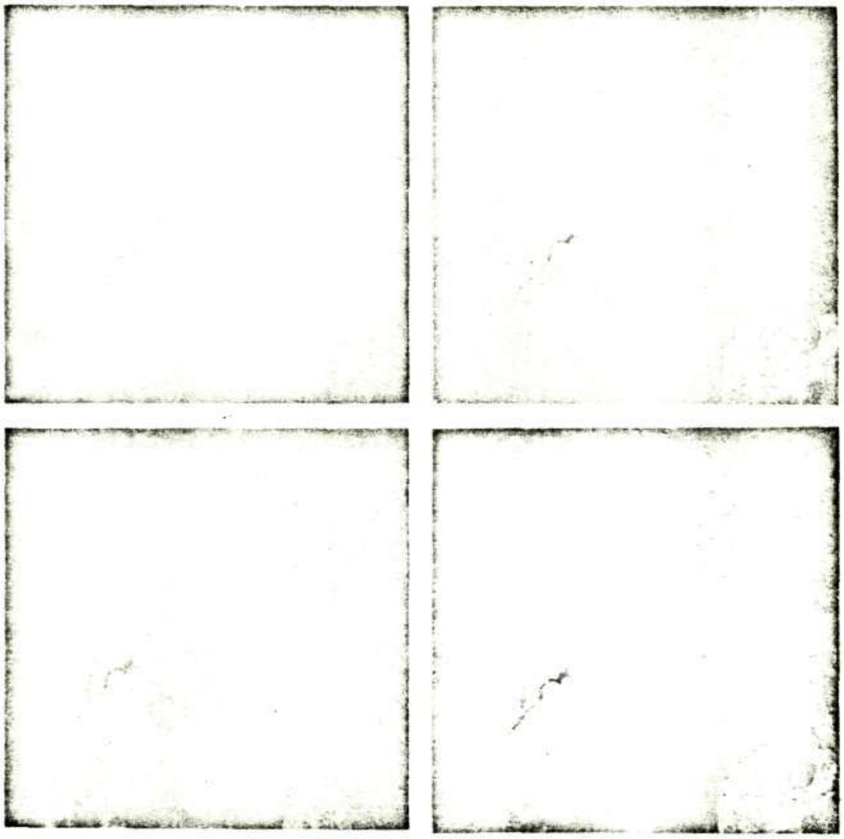

Figure 12. Example of multiband aerial photography of Test Site II (Extensive). A = Plus-X/Wratten 58; B = Plus-X/Wratten 25A; C = Aero IR/ Wratten 89B and D = Ektachrome IR/Wratten 12. RF = 1:90,000: camera focal length - 50mm. Note sunspot effects on A, B and D.

Film	Filter	Date	Local sun time 0900	1200	1500
			Corrected ASA Value		
Plus-X	58	Aug. 1, 1970	38	35	32
		" 10, "	27	43	72
		" 20, "	28	16	25
		Sept. 1, "	16	18	*
		" 11, "	12	10	8
	Mean ASA		24	24	34
Plus-X	25A	Aug. 1, 1970	64	60	45
		" 10, "	48	60	100
		" 20, "	38	32	43
		Sept. 1, "	27	28	*
		" 11, "	15	18	17
	Mean ASA		38	39	51
Aero Infrared	89B	Aug. 1, 1970	900	800	600
		" 10, "	650	500	1350
		" 20, "	550	360	510
		Sept. 1, "	360	450	*
		" 11, "	400	320	240
	Mean ASA		572	486	675
Infrared Ektachrome	12	Aug. 1, 1970	150	140	125
		" 10, "	115	200	350
		" 20, "	100	64	86
		Sept. 1, "	72	113	*
		" 11, "	100	80	40
	Mean ASA		107	119	150

* Missing

Table 1. Effects of time of day and date upon corrected ASA values of the different film-filter combinations used in tramway photography.

exposures for tramway photography were bracketed to ensure proper exposure. To assist in selecting future exposures, and to provide an eventual data base against which to study the effects of light and atmospheric conditions at the time of photography, the "corrected" ASA of each film-filter <u>at the time of photography</u> has been progressively computed. This was done by analyzing each set of photography and determining the f/stop and shutter speed necessary for optimum exposure (e.g., good shadow detail, bright areas not burned out). Applying these optimum exposure values, together with the light reading at the time of photography, back to the meter, gives the corrected ASA value for the conditions existing at the time of actual photography. It will be seen in Table 1 that these corrected ASA readings differed drastically with time and date of photography for the same film-filter combinations.

CONCLUSIONS

Since the data analysis stage of this project has not yet been reached, no conclusions are possible at this point.

As a first step in the analysis phase, various multiband image enhancements will be made with an optical combiner, and the interpretability of the enhanced images will be compared with that of the unenhanced color and black-and-white photographs. A determination also will be made of the relative importance of several photographic factors (sun angle, seasonal aspect, flight altitude, photographic scale, atmospheric condition, etc.) on the ability to detect disease-infected spruce trees by means of aerial photography.

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